United States Department of Agriculture
Science and Education Administration
Agricultural Research North Central Region Northern Regional Research Center
1815 North University Street
Peoria, Illinois
61604

October 31, 1980

SUBJECT: Seminar - Vegetable Oil for Diesel Fuel

TO: Attendees

Attached is a summary of the reports and widely diverse commentaries and comments we heard and participated in at the Vegetable Oil for Diesel Fuel Seminar held at the Northern Agricultural Energy Center on September 25, 1980. It is hoped this summary is accurate. At least it was the serious intent of those of us who worked on it to make it accurate.

As a follow-up to the Seminar, Dr. E. H. Pryde of the Northern Regional Research Center is developing sources for obtaining a "standard," minimum-refined vegetable oil diesel fuel (soybean-, sunflower-, and peanut oil-based) which can be purchased for test purposes. We expect to send you this list when it is completed.

In the meantime, the Northern Agricultural Energy Center and the Northern Regional Research Center are available to help and/or consult with you, especially regarding vegetable oil refining and modifying for use as a diesel fuel.

We are considering a second Seminar on vegetable oil for diesel fuel in a year or so and would appreciate your thoughts on scheduling such an event.

We appreciated the contributions all of you made in making the first Seminar successful and look forward to further contacts and technical interchanges with you.

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Attachments

Seminar-Vegetable Oil For Diesel Fuel
Northern Agricultural Energy Center
September 25, 1980

Introduction

The stated purpose of the seminar was: to exchange technical information about the refining, expelling, testing and utilization of vegetable oil for diesel engines, with special emphasis on problems requiring future research and development.

It was organized in three sections: Current Research, Industry Interests/Experience, and Future Research and Development.

Following J. J. Bruwer's presentation on his South African research, Dr. E. H. Pryde (Northern Regional Research Center (NRRC)) described work underway at the Oilseed Crops Laboratory having application to vegetable utilization as diesel fuel.

Other participants described research going on or expected to be initiated on soybean oil, sunflower oil, and peanut oil. This work was in progress at Carnegie Mellon University, University of Nebraska, University of Georgia, University of Illinois, Purdue University and South Dakota State University.

Commercial representatives invited to attend included the farm equipment industry, Ford, International Harvester, Deere & Company, Allis Chalmers, Caterpillar, J. I. Case, and Sperry New Holland; in the oil processing industry, Cargill, Archer Daniels Midland and A. E. Staley; and among the trade associations, American Soybean Association, National Soybean Crop Improvement Council, National Peanut Council, Illinois Soybean Program Operating Board, Sunflower Association of America and Farm and Industrial Equipment Institute.

Seminar Results

Total attendance was 87, primarily from the midwest but from as far away as California and New Jersey. The major diesel tractor manufacturers and oil processors were in attendance as well as many other scientists and agricultural engineers who had an interest in or were involved in adapting vegetable oil to diesel fuel. Although representatives of the Department of Energy (DOE) were invited, none could attend because of restrictions in travel; however, three DOE key persons called personally to express their disappointment in not being able to attend and participate in the Seminar and DOE was informally represented by Ed Lipinsky, Battelle, Columbus, Ohio.

During the time allowed for comments on presentations from participants, not formally scheduled, there were expressions from American Soybean Association, Deere & Company, International Harvester, Caterpillar, Cargill and Battelle. Also presented was a discussion concerning the North Central Region Research Proposal on vegetable oil for diesel fuel submitted to DOE and rejected; a presentation about the oil potential from growing crops in Nigeria (palm oil), and Texas (Chinese tallow tree); and an explanation on the type of work and effort being conducted by the Northern Agricultural Energy Center (NAEC).

There were numerous comments, suggestions, ideas and opinions expressed from the floor during the discussion period.

Research Reports

1. Sunflower Seed Oil as an Extension for Diesel Fuel in Agricultural Tractors. J. J. Bruwer, Director of Agricultural Engineering, Department of Agriculture and Fisheries, Silverton, 0127, Republic of South Africa.

   (Mr. Bruwer's presentation was based on papers presented at the 1980 Symposium of the South African Institute of Agricultural Engineers on June 11, 1980, copies of which may be obtained from Mr. Bruwer, and at the ASAE National Energy Symposium, September 29-October 1, 1980, Kansas City, Missouri.)

   An important observation was that thickening and gelation of lubricating oil may occur with a nonlinolenic oil such as sunflower oil as well as with soybean oil, which contains 7-8% linolenic acid.

   Sunflower seed oil cannot yet be recommended as a fuel in diesel engines, because of problems arising from incomplete combustion in direct injection engines. The methyl and esters of sunflower oil more nearly approach the viscosity and volatility properties of diesel oil and have given better results in initial tests than does the oil itself. Future investigations will include long-term tests with the esters and ester blends in engines operating under cyclic loads, injection system modification, lubricating oil additions, and on-farm processing.

2. Vegetable Oils as Diesel Fuel: An Overview. E. H. Pryde.

   The long-term use of vegetable oils in farm tractors with direct injection diesel engines is neither economically nor technically feasible at present. Nevertheless, vegetable oils or their esters may be used on a short-term basis in an emergency situation. There is a favorable energy output/input ratio. In carrying out engine tests with vegetable oils, the oil must be thoroughly characterized with respect to iodine value or fatty acid composition, free fatty acids, phosphatides, and degree of refining.

The problem of incomplete combustion in the direct injection diesel engine is related to improper atomization of the fuel resulting from the high viscosity. Heating the fuel line is an example of one possible approach to reducing the viscosity. The presence of soybean oil was demonstrated by gas chromatography in lubricating oil from an engine burning a 50:50 mixture of soybean oil and diesel. The transesterification of vegetable oils with simple alcohols in the presence of a base catalyst is readily carried out and is benefited by production of a valuable byproduct, glycerol. 1-Butanol as well as ethanol should be considered for the transesterification reaction since both may be produced by fermentation of agricultural products.

3. Peanut Oil. Lawton Samples, Extension Engineering Department, University of Georgia, Tifton, Georgia 30602.

Peanuts contain 50% oil, but there are varieties available having as much as 62% oil to bring total potential yield of oil up to 2,100 lb/acre. There is a 4:1 energy gain (including hulls) in producing peanuts. If allotments could be removed, peanut acreage would increase tremendously. Of current peanut production, 63% is produced under irrigation. When peanuts are grown on sandy, loamy land, 95% of the crop can be recovered.

4. Engine Tests. J. B. Liljedahl and J. S. Marks, Agricultural Engineering Department, Purdue University, West Lafayette, Indiana 47907.

Engine tests confirmed Mr. Bruwer's results with a 50:50 diesel oil/sunflower oil mixture. There were no problems except for 3-4% power loss and thickening of the lubricating oil. It would be desirable to develop a laboratory test that would indicate when the lubricating oil thickening will be a problem.

5. Sunflower Oil as a Diesel Fuel. G. L. Pratt, Chairman, Agricultural Engineering Department, North Dakota State University, Fargo, North Dakota.

(Refer to the Cooperative Extension Service Report No. 13AENG-5 of North Dakota State Uniersity by V. Hofman et al distributed at the September 25 meeting.)

The only deterrent to farmers use of vegetable oils is the effect of long-term use. Such studies are underway at North Dakota State University. Both on-farm and co-op units for extruding the oil are being looked at. A co-op plant would cost about $150,000 with $50,000 required for the extruder alone.

6. Palm Oil as a Diesel Fuel. A. J. Akor, Michigan State University, East Lansing, Michigan.

(Refer to "The Oil Palm Industry as an Energy Resource: Prospects and Problems" by A. J. Akor, Paper No. PR80-004, ASAE Pacific Region, Annual Meeting, Hile, Hawaii, March 18-10, 1980.)

The oil palm is the greatest producer of oil per unit of land now in commercial production. The high proportion of saturated fatty acids in the oil (which has a solidification point or titer of about 43 C) may limit its use in other than tropical climates without engine modification for heating the fuel or without winterization of the oil. In an engine equipped with a pre-combustion chamber, palm oil gave somewhat lower indicated thermal efficiency than some other oils. BHT (butylated hydroxytoluene) and BHA (butylated hydroxyamisole) were used as antioxidants to increase oil stability. It is likely that no one oil will supply all diesel energy needs, but a combination of many different oils.

7. Engine Tests. N. Sauter, John Deere and Company, Technical Center, Moline, Illinois.

   Engine test results are to be published in a SAE paper. Abnormal deposits were observed in many parts of the engine when 100% sunflower oil was burned in a diesel engine with direct injection, under transient load conditions. The power level has a direct effect on the amount of deposits. The thickening of the lubricating oil and bearing distress in the engine tests of John Shipp, John Deere dealer, Russellville, Kentucky, were also described when a 50:50 combination of soybean oil and diesel oil were used. A possible solution is a practical engine redesign.

8. Soybean Oil as a Diesel Fuel. R. McCutchen, Caterpillar Tractor Company, Peoria, Illinois.

   After 200 hours under variable load in an engine equipped with a pre-combustion chamber, 100 percent hexane-extracted, water-degummed crude soybean oil gave no indication of any problems in the engine cylinder. Carbon build-up in the pre-combustion chamber was observed after 200 hours, but the deposit flaked off readily after building up to about 0.5 mm. Field trials in Brazil are being conducted with 30:70 soybean oil (degummed):diesel oil mixtures.

9. The Chinese Tallow Tree. H. William Scheld, Department of Biology, University of Texas.

The Chinese Tallow Tree is adapted to saline, water-logged soils and has become naturalized along the coastline from North Carolina to Texas and particularly in the Houston area. It is valued as an ornamental tree but has the potential of producing 5000 pounds of fat per acre. There are two types of fat present, the outer fat coating being similar to cocoa butter and the inner kernel fat having drying properties in between linseed and tung oils. The fat has been tested in a diesel engine on a short-term basis, and the results were satisfactory.

Research and Development Needs

The questions, concerns and comments paraphrased below were elicited from the audience and represent the results of a loosely structured discussion in response to specific questions.

I. What are the major problems in making vegetable oils available for successful (satisfactory) use as diesel fuel in farm tractors?

1. Extraction/Expelling of Oil-On-Farm versus Co-op or Commercial Processing.

Extrusion is a feasible process for expelling oil (particularly for high oil content oilseeds such as sunflower seed and peanut) but may be too capital intensive and too complex for on-farm operation.

Extraction with hexane, which is more suitable for low oil content oilseeds such as soybeans, presents difficulties in on-farm operation in both safety and complexity. Since on-farm extraction is not a process that would be under time constraints, the possibility exists for batch extracting the seed oil over long periods with gasoline or diesel fuel. Over such periods the question needs to be raised concerning undesirable components being extracted along with the oil. In addition, the removal of gasoline or diesel fuel from the meal to salvage it for feeding seems an intractable problem.

If extraction or expelling is done on-farm the fate of the defatted meal needs consideration. Few oilseed producers would have the livestock necessary to dispose of the meal directly. A commercial (or co-op) processor might more readily develop meal markets. Cargill, for example, already has a market for sunflower meal at 80% of the price of soybean meal.

Standardization of oil quality could be a major problem for an on-farm operation and without good quality control on the oil, engine damage may be a continuing problem. A large enough operation could provide analytical facilities to provide reliably prepared oil.

2. Oil Refining

It was evident from the discussion and papers presented that we lack adequate detailed information on the relation between extent of oil refining and engine performance. Vegetable oils present both problems and opportunities and there is a much expertise in oil processing, both in the vegetable oil industry and the petroleum industry, that can be applied here.

Some oil processing techniques, e.g., hydrogenation—are probably not feasible at the farm level. Some refining treatments, e.g., transesterification—might be done at the farm level. The critical need is to determine the minimum refining needed and this will vary with the particular oil—soybean, sunflower, peanut—being considered. We also need to know the variability tolerable in current diesel fuels particularly in regard to the potential of vegetable oils for blending with diesel fuels.

3. Oil Standardization

There is an ASTM committee on alternate fuels but it is not believed to be very active. A joint meeting between those involved in engine fuel characterization (e.g., ASTM) and those familiar with vegetable oil characterization (e.g., American Oil Chemists' Society, AOCS) should develop standards for guidance for those engaged in either engine tests or oil extraction and processing. Battelle already has a list of vegetable oil properties relative to their use for diesel fuel. Characterization must certainly include such features as fatty acids present, phosphorus, sulfur, etc.

The complexity of the problems is illustrated by the comment that the higher the quality of the (sunflower) oil, the more difficulties were encountered in engine operation. Best performance with sunflower was with degummed oil filtered through a 5 micron filter.

For storage, it was claimed that, although crude vegetable oil can be expected to change during storage, exclusion of air and light in one experiment gave at least 8 months of stable storage.

Engine testing needs to be carried out to determine the minimum processing needed for reliable long-term engine operation. Certainly, in dealing with vegetable oils, as with alcohols, it needs to be borne in mind that food grade quality is not required.

Although engine design is closely related to diesel oil specifications, we do not want necessarily to start with the specifications for diesel oil to establish standards for vegetable oils. There are additional tests needed for vegetable oils such as those mentioned above.

4. Engine Design

Diesel engine design has been developed to a satisfactory state over the years and now we want to change the fuel. The redesign of diesel engines that may be needed to use vegetable oils will take time. Some cautioned that we should not move too fast. On the other hand it may be more reasonable to refine the oil for use in current engines.

To make effective use of vegetable oils in diesel engines, either the engine, the fuel or both, must be modified. As the South African report indicated, modification of sunflower oil to make methyl or ethyl esters is a most promising route. The sunflower esters have viscosity and volatility properties more nearly approaching those of diesel oil compared to the original sunflower oil. Some suggested that pyrolysis of vegetable oils may be another route to a better diesel fuel.

5. Funding

Although DOE personnel were not present, DOE was represented by Ed Lipinsky of Battelle. It was evident that DOE should make funds available for long-term engine tests with vegetable oils. Costs for a single test of 1000 hours or more involving up to 5000 gallons of fuel would be about $10,000 for the vegetable oil alone. Also apparent was the need for supplying several standard vegetable oil fuels for tests in a variety of engine designs and makes. Costs then could approach one million dollars.

6. General Comments

If the farmer produces his own vegetable oil, he will need a storage tank to store oil from one season to the next. He could store diesel oil, purchasing the oil in an off-season when there are ample supplies. However, if the OPEC countries become involved in war, there may not be any diesel oil available at any time. Furthermore, the farmer, in using vegetable oil in diesel engines, is creating a new market for such oils that will relieve oversupplies and eventually increase return to the farmer.

Several participants noted that vegetable oils as sources of fuel for peak load use at utilities and for home heating need also to be investigated.

Demand/increase for soybeans will continue at the rate of 5-8% per year provided that adequate markets for the oil can be found.

II. What can we do about the problems?

1. Definition of fuels and engine tests.

The vegetable oils used for engine tests must be adequately characterized to permit correlation of engine test results with the composition of the oil. It would be desirable to have sufficient quantities of thoroughly characterized oils so that engine tests at different locations could be run on the same oil. A list of tests methods by AOCS Official Methods is attached. A list of ASTM test methods will also be made available. A joint ASTM/AOCS committee may be desirable to develop vegetable oil standards. Analyses can be carried out by 70 ASTM-certified laboratories distributed throughout the United States.

Similarly, engine tests need to be defined to provide adequate cycling of full, partial, and no loads on the engine. (Vegetable oils apparently have more severe problems with coking, carbon deposits, and lubricating oil thickening than diesel oil when the engine is on partial load.) Cooperation with the Engine Manufacturer's Association, which is active in alternate fuels work, should be sought in testing engines and fuels. The type, design, and make of the engine need to be specified in publications of test results. Both laboratory dynamometer and long-term tests will be needed.

2. Funding

There should be a redistribution of monies available for research on use of vegetable oils for fuel to eliminate duplication of research effort. Funding for research will be a continuing problem, but this problem might be simplified by a closer working relationship of all the various research sectors in attendance. Critical evaluation and coordination, perhaps by DOE or USDA personnel, are needed for on-going research in vegetable oil fuels.

3. Cooperation

The NRRC has expertise in vegetable oil analyses and refining proceses. Analyses and tests can be made at NRRC in cooperative research programs but not for routine analyses made in large numbers on a day-to-day basis. Cooperation can be arranged by negotiating a relatively simple Memorandum of Understanding.

Conclusions

As a result of informal communication and cross-talk among the university, engine and equipment manufacturers, vegetable oil refinery, government, and farm representatives present, good progress was made in defining the problems and the needs as well as summarizing the status quo of research at several university and industry installations in the use of vegetable oils as diesel fuel. The urgency of the farmer's need for energy independence without damage to his farm equipment was transmitted to all present and generated a good deal of enthusiasm.

Vegetable oils can substitute for diesel oil in engines having pre-combustion chambers but not in direct injection engines.It is probable that simple esters of vegetable oils will perform well in either type of engine as a result of improved viscosity and volatility properties.

There are substantial regional differences in approach to use of vegetable oils. Peanut, soybean, and sunflower oils are the major ones to consider for the United States, but palm and other, untapped sources need also be considered, in particular those that do not conflict with food needs.

Either modification of the direct-injection engine (e.g. heated fuel lines, redesigned injection system) or of the vegetable oil (e.g. transesterification to simple esters, pyrolysis) will be necessary. Transesterification appears to hold the greatest potential at the moment (see attached selected bibliographies).

Among needs brought into focus were the following:

1. Long-term engine tests under standard, reproducible conditions.

2. Standardization of and sources of supply for vegetable oil materials being tested (test methods attached; sources under discussion).

3. Coordination and cooperation among the various groups. The NAEC personnel stand ready to assist in such cooperation.

4. Development of on-farm technology, or at least of information that will permit making a decision, which may be different for the various oilseeds, on whether a co-op size plant might not be more efficient and serve the farmers' needs more effectively.

Attachments

1. List of American Oil Chemists' Society (AOCS) Test Methods pertinent to the Use of Vegetable Oils as Diesel Fuel.

2. Pyrolysis of Vegetable Oils as a Route to Hydrocarbon Fuels. A Selected Bibliography.

3. Transesterification of Vegetable Oils. A Selected Bibliography.

4. Vegetable Oils and Alcohol as Diesel Fuel. A Selected Bibliography.

(A list of attendees was distributed at the Seminar and is also available upon request.

10-16-80

List of American Oil Chemists' Society (AOCS) Test Methods[a] Pertinent to the Use of Vegetable Oils as Diesel Fuel

Test Methods	Analysis For	AOCS Method Number
Acid Value	Free fatty acids	Cd 3a-63
Active Oxygen Method	Fat stability	Cd 12-57
Ash[b]	Inorganic residues	Ca 11-55
Cold Test	Resistance to crystallization	Cc 11-53
Congeal Point[b]		Cc 14-59
Copper	Inorganics	Ca 15-75
Fatty Acid Composition[b] by Gas Chromatography		Ce 1-62
Flash Point, Closed Cup Method	Oils that contain volatiles or that flash below 300 F	Cc 9b-55 (ASTM D93-52)
Flash Point[b], Open Cup Method	Smoke, flash, and fire points for oils that flash above 300 F	Cc 9a-48 (ASTM D92-33)
Free Fatty Acids[b]	Free fatty acid content	
In cottonseed		Aa 6-38
In Fats and Oils		Ca 5a-40
In Peanuts		Ab 5-49
In Soybeans		Ac 5-41
Hydrocarbons in Fats	Naturally occurring hydrocarbons	Ca 6c-65
Hydroxyl Value (for castor oil)		Cd 13-60
Insoluble Impurities		Ca 3-46
Iodine Value	Unsaturation	Cd 1-25
Iron	Inorganics	Ca 15-75
Melting Point[b]		
Capillary Tube Method		Cc 1-25
Wiley Method		Cc 2-38
Methyl Ester Preparation	Fatty acid composition	Ce 2-66

Test Method	Analysis For	AOCS Method Number
Moisture		
Distillation Method		Ca 2e-55
Karl Fischer Method		Tb 2-64
Moisture and Volatile Matter		
Air Oven Method		Ca 2c-25
Hot Plate Method		Ca 2b-38
Vacuum Oven Method		Ca 2d-25
Nickel	Inorganics	Ca 15-75
Peroxide Value[b]	Oxidized fats	Cd 8-53
Phosphorus[b]	Phosphatides (gum-formers)	Ca 12-55
Refractive Index		Cc 7-25
Sampling		C 1-47
Saponification Value		Cd 3-25
Soap in Oil[b]	Metal salts of fatty acids	Cc 15-60
Softening Point		Cc 3-25
Specific Gravity[b]		Cc 10a-25
Soluble Mineral Matter	Lime and other soaps	Ca 4-25
Unsaponifiable Matter	Alcohols, sterols, pigments and hydrocarbons	Ca 6a-40
Viscosity[b]		ASTM method

[a]American Oil Chemists' Society, Official and Tentative Methods, The Society, 508 South Sixth Street, Champaign, Illinois 61820, 1979, 2 volumes, $110 per set.

[b]Minimum analysis needed for vegetable oils to be used in engine tests.

Methods similar to the American Oil Chemists' Society (AOCS) methods also can be found in the following books:

1. Horwitz, W., Editor, Official Methods of Analysis of the Association of Official Analytical Chemists, 13th ed., The Association, PO Box 540, Benjamin Frankin Station, Washington, D.C. 20044, 1980, pp. 437-465.

2. Paquot, C., Editor, Standard Methods for the Analysis of Oils, Fats, and Derivatives, International Union of Pure and Applied Chemistry, Applied Chemistry Division, Commission on Oils, Fats, and Derivatives, Pergamon Press, Oxford and New York, 1979.

10-17-80

Pyrolysis of Vegetable Oils as a Route to Hydrocarbon Fuels

A Selected Bibliography

Chang, C.-C. and S.-W. Wan. China's motor fuels from tung oil. Ind. Eng. Chem. 39(12):1543-1548 (1947).

Cheng, Fa-Wu. China produces fuels from vegetable oils. Chem. Met. Eng. 52(1):99 (1945). Chem. Abstr. 39:4441 (1945).

Dalal, N. M. and T. N. Mehta. Cracking of vegetable oils. J. Indian Chem. Soc., Ind. News Ed. 2:213-245 (1939). Chem. Abstr. 34:6837 (1940).

Egloff, G. and J. C. Morrell. The cracking of cottonseed oil. Ind. Eng. Chem. 24:1426-1427 (1932).

Gallo, G. and R. Correlli. The synthetic production of liquid fuels. Atti congresso maz. chim. pura applicata 1923:257. Chem. Abstr. 18:2594 (1924).

Haag, W. D., P. G. Rodewald, and P. B. Weisz. Catalytic production of aromatics and olefins from plant materials. Preprints, Division of Petroleum Chemistry, Inc., American Chemical Society 25(3):650-656 (August 1980).

Koo, E. C. and S.-M. Cheng. The manufacture of liquid fuel from vegetable oils. Chinese Industry 1:2021-2039 (1935). Chem. Abstr. 30:837 (1936).

Mailhe, A. Petroleum from peanut oil. Chaleur et industrie 5:3-5 (1924). Chem. Abstr. 18:1744 (1924).

Mailhe, A. The preparation of petroleum from vegetable and animal oils. Chemie et industrie Special No. 80-88 (May 1923). Chem. Abstr. 17:3094 (1923).

Petroff, S. and A. E. Prats. Process of producing gasoline and other hydrocarbons from coconut oil and related animal and vegetable oils and fats. U.S. Patent 2,437,438 (March 9, 1948).

Rao, K. V. C. Production of hydrocarbons by thermolysis of vegetable oils. U.S. Patent 4,102,938 (July 25, 1978).

Sato, M. et al. Preparation of fuel oil by the dry distillation of calcium soap of soybean oil. IV. Comparison with magnesium soap. J. Soc. Chem. Ind. (Japan) 30:242-245 (1927). V. Hydrogenation of the distilled oil. Ibid. 245-252. VI. The reaction mechanism of thermal decomposition of calcium and magnesium salts of some higher fatty acids. Ibid. 261-267. Chem. Abstr. 21:2371-2372 (1927).

Traitler, H. and K. Kratzl. On the formation of degradation products from the pyrolysis of tall oil fatty acids with kraft lignin. J. Am. Oil Chem. Soc. 57:153-156 (1980).

Weisz, P. B., W. D. Haag, and P. G. Rodewald. Catalytic production of high-grade fuel (gasoline) from biomass compounds by shape-selective catalysts. Science 206:57-58 (1979).

Transesterification of Vegetable Oils

A Selected Bibliography

Allen, H. D. and W. A. Kline (to Colgate-Palmolive-Peet Co.). Process for treating fats and fatty oils. U.S. Patent 2,383,579 (August 28, 1945).

Arrowsmith, C. J. (to Colgate-Palmolive-Peet Co.). Treating fatty materials. U.S. Patent 2,383,580 (August 28, 1945).

Braconier, F. F. and J. M. J. Hermesse (to Societe Belge de l'Azote et des Produits Chimiques). Process for the alcoholysis of oils, fats, and waxes. U.S. Patent 2,727,049 (December 13, 1955).

Bradshaw, G. B. (to E. I. du Pont de Nemours and Co.). Process for refining fats. U.S. Patent 2,398,492 (April 16, 1946).

Bradshaw, G. B. and W. C. Meuly (to E. I. du Pont de Nemours and Co.). Preparation of detergents. U.S. Patent 2,360,844 (October 24, 1944).

Bradshaw, G. B. and W. C. Meuly (to E. I. du Pont de Nemours and Co.). Process of making pure soaps. U.S. Patent 2,271,619 (February 3, 1942).

Bradshaw, G. B. New soap process. Soap, Cosmetics, Chemical Specialties 18(5):23-26 (1942).

Dreger, E. E. (to Colgate-Palmolive-Peet Co.). Method of treating fatty glycerides. U.S. Patent 2,383,596 (August 28, 1945).

Elsdon, G. D. Alcoholysis and composition of coconut oil. Analyst 38:8-11 (1913); Chem. Abstr. 7:1627 (1913).

Feuge, R. O. and A. T. Gros. Modification of vegetable oils. VII. Alkali catalyzed interesterification of peanut oil with ethanol. J. Am. Oil Chem. Soc. 26:97-102 (1949).

Formo, M. W. Ester reactions of fatty materials. J. Am. Oil Chem. Soc. 31:548-559 (1954).

Gauglitz, E. G., Jr. and L. W. Lehman. The preparation of alkyl esters from highly unsaturated triglycerides. J. Am. Oil. Chem. Soc. 40:197-198 (1963).

Glossop, G. A. (to Colgate-Palmolive-Peet Co.). Treating fatty glycerides. U.S. Patent 2,383,599 (August 28, 1945).

Hunn, J. V. (to The Sherwin-Williams Co.). Process of alcoholysis. U.S. Patent 2,654,767 (October 6, 1953).

Keim, G. I. (to Colgate-Palmolive-Peet Co.). Treating fats and fatty oils. U.S. Patent 2,383,601 (August 28, 1945).

Keim, G. I. (to Colgate-Palmolive-Peet Co.). Treating fats and fatty oils. U.S. Patent 2,383,602 (August 28, 1945).

Lehman, L. W. and E. J. Gauglitz, Jr. The preparation of alkyl esters from highly unsaturated triglycerides. II. J. Am. Oil. Chem. Soc. 43:383-384 (1966).

Percy, J. H. (to Colgate-Palmolive-Peet Co.). Treatment of fatty glycerides. U.S. Patent 2,383,614 (August 28, 1945).

Peterka, V. and M. Zbirovsky. Butanolyse von palmitinsauremethylester. Coll. Czech. Chem. Comm. 35:1010-1012 (1970).

Plachenka, J. and L. Jeromin. Anwendung von Rechenprogrammen bei der Simulation and Optimierung von Rektifizieranlagen in der fettchemischen Industrie. Fette Seifen Anstrichm 82:300-307 (1980).

Price, D. and F. J. Sprules (to Nopco Chemical Co.). Transesterification process. U.S. Patent 2,543,421 (February 27, 1951).

Schlenk, H. and R. T. Holman. Methanolysis of triglycerides by an anion exchange resin. J. Am. Oil Chem. Soc. 30:103-104 (1953).

Smith, M. K. (to The Baker Castor Oil Co.). Processing of producing esters. U.S. Patent 2,486,444 (November 1, 1949).

Sprules, F. J. (to Nopco Chemical Co.). Production of fatty esters. U.S. Patent 2,494,366 (January 10, 1950).

Sridharan, R. and I. M. Mathai. Transesterification reactions. J. Scient. Ind. Res. 33:178-187 (1974).

Trent, W. R. (to Colgate-Palmolive-Peet Co.). Process of treating fatty glycerides. U.S. Patent 2,383,632 (August 28, 1945). Reissued (No. 22,751) April 30, 1946.

Trent, W. R. (to Colgate-Palmolive-Peet Co.). Process for treating fatty glycerides. U.S. Patent 2,383,633 (August 28, 1945).

Wright, H. J., J. B. Segur, H. V. Clark, S. K. Coburn, E. E. Langdon, and R. N. DuPuis. Oil Soap 21:145-148 (1944).

10-15-80

Vegetable Oils and Alcohol as Diesel Fuel

A Selected Bibliography

Akor, A. J. The oil palm industry as an energy resource: Prospects and problems. Paper No. PR 80-004, presented at the American Society of Agricultural Engineers, Pacific Region Annual Meeting, Hilo, Hawaii, March 18-20, 1980.

Aggarwal, J. S., H. D. Chowdhury, S. N. Mukerji, and L. C. Verman. Indian vegetable oils as fuels for diesel engines. Bulletin of Indian Industrial Research No. 19, 3rd ed., Council of Scientific and Industrial Research, New Delhi, India, 1953, 34 pp. (Chem. Abstr. 47:2460g, 1953).

Anon. Indian vegetable fuel oils for diesel engines. Gas and Oil Power, May 1942, pp. 80-85.

Anon. Soy oil test as tractor fuel is successful. Progressive Farmer (Midmonth Soybean Edition), April 1980, p. 24.

Anon. Soy oil: A future farm fuel? Soy World 2(3):6 (1980).

Anon. Soy oil fuels questions. Soybean Digest 40(8) SID-1 (1980).

Baker, A. W. and R. L. Sweigert. A comparison of various vegetable oils as fuels for compression-ignition engines. Am. Soc. Mech. Eng., Proceedings, 19th Oil and Gas Power Conference, May 21-24, 1947, Cleveland, Ohio, pp. 40-48 (Chem. Abstr. 43:4827g, 1949).

Bruwer, J. J., B. van D. Boshoff, F. J. C. Hugo, J. Fuls, C. Hawkins, and A. N. van der Walt. Sunflower seed oil as an extender for diesel fuel in agricultural tractors. Report of Division of Agricultural Engineering, Department of Agriculture and Fisheries, Silverton, Republic of South Africa, June 11, 1980.

Bruwer, J. J., B. van D. Boshoff, F. J. C. Hugo, L. M. du Plessis, J. Fuls, C. Hawkins, A. N. van der Walt, and A. Engelbrecht. Sunflower seed oil as an extender for diesel fuel in agricultural tractors. Presented at the 1980 Symposium of the South African Institute of Agricultural Engineers, June 11, 1980.

Bruwer, J. J., B. V. D. Boshoff, F. Hugo, and A. van der Walt. The utilization of sunflower oil as a fuel in diesel tractor engines. Presented at the National Energy Symposium of the American Society of Agricultural Engineers, Kansas City, Missouri, September 29-October 1, 1980.

Chancellor, W. J. Vegetable oils as fuels for diesel engines. Presented at the American Society of Agricultural Engineers, Pacific Region Annual Meeting, Hilo, Hawaii, March 18-20, 1980.

Cochran, B. J., L. R. Daniel, Jr., and J. C. Baldwin. "Diesol"--an alternative fuel for compression ignition engines. Presented at the National Energy Symposium of the American Society of Agricultural Engineers, Kansas City, Missouri, September 29-October 1, 1980.

Engelman, H. W., D. A. Guenther, and T. W. Silvis. Vegetable oil as a diesel fuel. Am. Soc. Mech. Eng., Proceedings of the Energy Technology Conference and Exhibition, November 5-9, 1978, Houston, Texas, pp. 1-8.

Erickson, D. R. and P. Dixon. Soy oil as diesel fuel: Economic and technical perspectives. American Soybean Association, St. Louis, Missouri, 4 pp.

Goodier, B. G., M. D. Heilman, P. R. Nixon, and W. F. Schwiesow. Sunflower oil--an emergency farm fuel? Agricultural Engineering 61(3):20-21 (1980).

Hofman, V., W. E. Dinusson, D. C. Zimmerman, D. L. Helgeson, and C. Fanning. Sunflower oil as a fuel alternative. Cooperative Extension Service, Report No. 13 AENG-5, North Dakota State University, 1980, 4 pp.

Kenward, J. Vegetable oils as fuels? Yes! (Interview with Dr. Graeme Quick, Australian Ag Engineer.) The Sunflower, April 1980, pp. 18-20.

Miller, G. L., J. L. Smith, and J. P. Workman. Engine performance using butanol fuel blends. Agricultural Engineering, in press.

Miller, V. Can you burn vegetable oils in your diesel? Progressive Farmer, June 1980, pp. 22-23.

Narasimhan, T. L., M. R. K. Rao, and H. A. Havemann. Alcohol as principal fuel in high speed diesel engines. J. Indian Insti. Sci. 38B, 224-247 (1956) (Chem. Abstr. 51:6120h, 1957).

Noon, R. Agri-feed potentials of butanol/acetone production. An alternative to ethanol for a gasoline substitute. Kansas Energy Office, 214 West Sixth, Topeka, Kansas, 1980, 10 pp.

Noon, R. and T. Hochstetler. Soybean oil as a renewable fuel. Kansas Energy Office, 214 West Sixth, Topeka, Kansas, 1980, 14 pp.

Panchapakesan, N. R., K. V. Gopalakrishnan, and B. S. Murthy. Factors that improve the performance of an ethanol-diesel oil dual-fuel engine. International Symposium on Alcohol Fuel Technology, Wolfsburg, Germany, November 22-23, 1977, Vol. 2, Volkswagen Werk AG in cooperation with the German Federal Ministry for Research and Technology, pp. 2-2(1)-2-2(8).

Rao, M. R. K. and Y. M. Balakrishna. Wear in high speed diesel engines operating on power alcohol as principal fuel. J. Ind. Inst. Sci. 39B, 17-25 (1957).

Sandvik, M. W. Sun oil shows promise as fuel. The Sunflower, October/November 1979, pp. 18-19.

Seddon, R. H. Vegetable oils in commercial vehicles. Gas and Oil Power, August 1942, pp. 135-142.

Sklar, S. Will butanol be our next on-farm liquid fuel? Gasahol USA, August 1980, pp. 19, 30.

Strait, J., J. J. Boedicker, and K. L. Johansen. Diesel oil and ethanol mixtures for diesel-powered farm tractors. Final Report to the State of Minnesota Energy Agency, December 29, 1978, 40 pp.

Walton, J. The fuel possibilities of vegetable oils. Gas and Oil Power 33, 167-168 (July 1938).

Warmington, C. Flower power. Sunflower (Australia), November 1979, pp. 10-11.

Wiebe, R. and J. Nowakowska. The technical literature of agricultural motor fuels. U.S. Department of Agriculture Bibliographical Bulletin No. 10, Washington, D.C., 1949, pp. 183-195.

Wrage, K. E. and C. E. Goering. Technical feasibility of diesohol. Paper No. 79-1052. Presented at the 1979 Summer Meeting of the American Society of Agricultural Engineers and the Canadian Society of Agricultural Engineering, Winnipeg, Canada, June 24-27, 1979.